(12)

AD-A145 049

TECHNICAL NOTE

TN NO: N-1692

TITLE: HANGAR DESTRATIFICATION INVESTIGATION

AUTHOR: J. Ashley

DATE: April 1984

SPONSOR: Naval Material Command

PROGRAM NO: Z0829-01-111C

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

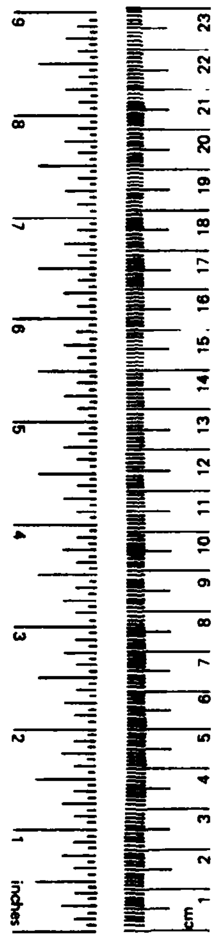
84 08 30 010

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

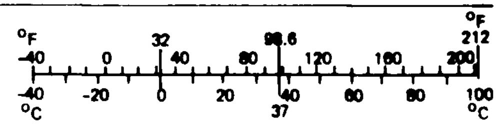
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TN-1692	2. GOVT ACCESSION NO. DN687061	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HANGAR DESTRATIFICATION INVESTIGATION		5. TYPE OF REPORT & PERIOD COVERED Not final; FY82 – FY83
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. Ashley		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS NAVAL CIVIL ENGINEERING LABORATORY Port Hueneme, CA 93043		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 63724N; ZO829-01-111C
11. CONTROLLING OFFICE NAME AND ADDRESS Chief of Naval Material Washington, DC 20360		12. REPORT DATE April 1984
		13. NUMBER OF PAGES 35
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HVAC, Energy conservation, Hangars, Stratification

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measurements made in military hangars indicated that stratification, the existence of a layer of hot air in a structure's overhead, is a typical phenomenon. Five destratification concepts (three commercial and two Navy-developed) were evaluated to determine the effectiveness and the adaptability of each concept for hangar applications. Only the Navy-developed concepts were found practical for hangar applications. Destratifier design and application guidelines were developed and are presented in the report.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Library Card

Naval Civil Engineering Laboratory
HANGAR DESTRATIFICATION INVESTIGATION, by J. Ashley
TN-1692 35 pp illus April 1984 Unclassified

1. Energy conservation 2. Stratification I. ZO829-01-111C

Measurements made in military hangars indicated that stratification, the existence of a layer of hot air in a structur's overhead, is a typical phenomenon. Five destratification concepts (three commercial and two Navy-developed) were evaluated to determine the effectiveness and the adaptability of each concept for hangar applications. Only the Navy-developed concepts were found practical for hangar applications. Destratifier design and application guidelines were developed and are presented in the report.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

CONTENTS

INTRODUCTION

Measurements made in five hangars (two U.S. Air Force and three U.S. Navy) indicated that stratification, the existence of a layer of hot air in the structure's overhead, is a typical phenomenon in heated hangars (Ref 1). This phenomenon results in increases in energy consumption because of the following:

- the increased temperature difference across the roof and upper wall surfaces increases the amount of heat transferred from inside a structure to the outside

- chimney effect increases the structure's air infiltration rate

- unused heat is wasted heat

Five destratification concepts (three commercial, one developed by NCEL and one suggested by the Naval Facilities Engineering Command Atlantic Division*) were evaluated to determine the effectiveness and adaptability of each concept for hangar applications. This report presents the design criteria for the NCEL destratification concept and the results of the evaluations of all the concepts.

DESTRATIFICATION CONCEPTS

The five destratification concepts evaluated are as follows:

- Destratification tube - commercial (Figure 1): The unit consists of a small blower mounted on top of a tube or duct which transverses from floor to ceiling. The fan blows hot ceiling level air down through the duct to the floor level where the hot air mixes with the cooler floor level air.

- Ceiling fan - commercial (Figure 2): A fan, mounted at the ceiling level, blows hot air down toward the floor where it is mixed with the cooler floor level air.

- Floor blower - commercial (Figure 3): A blower placed at the floor level blows cool floor level air upward toward the ceiling where it mixes with the hot ceiling level air.

*LANTDIV.

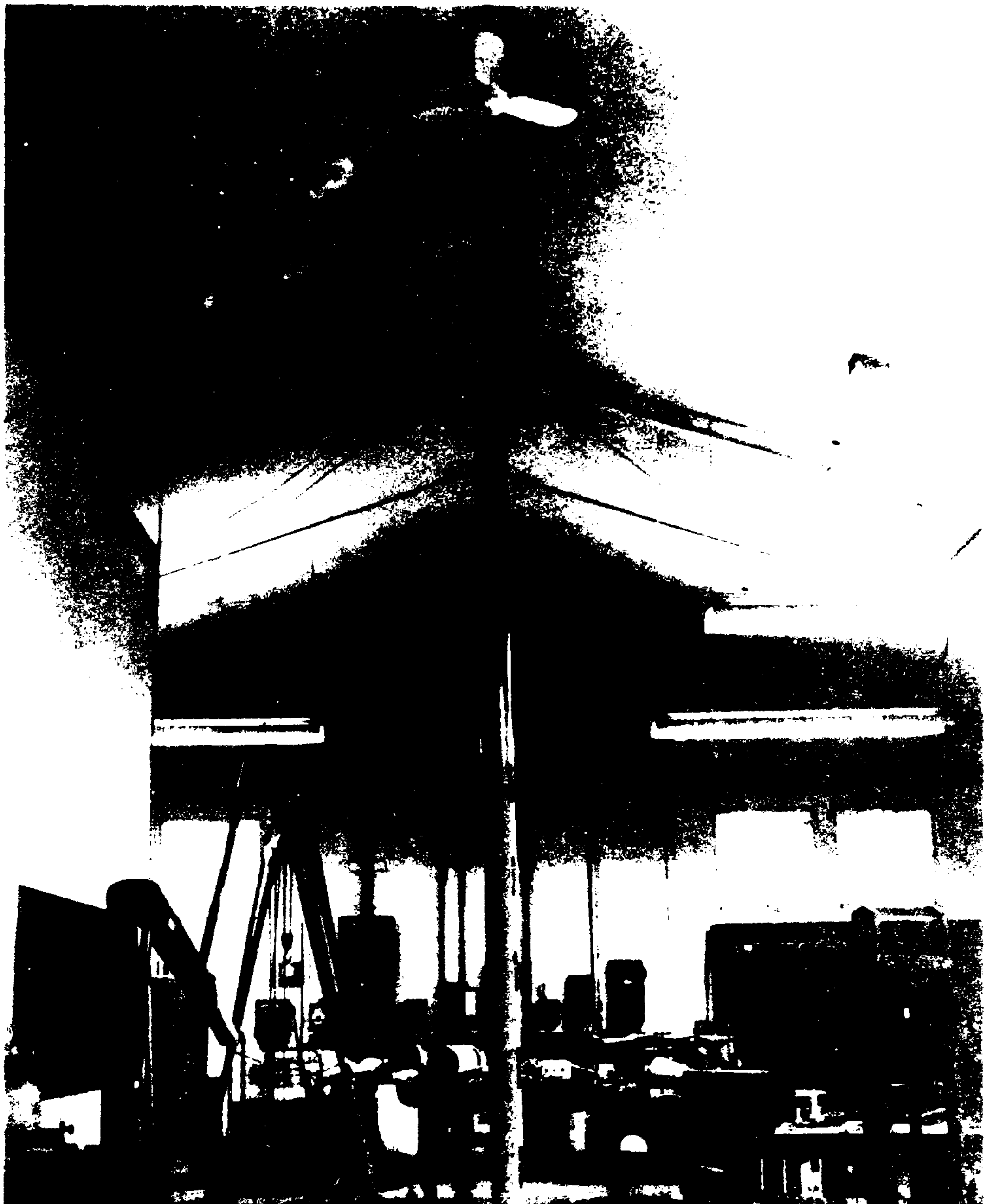


Figure 1. Destratification tube.

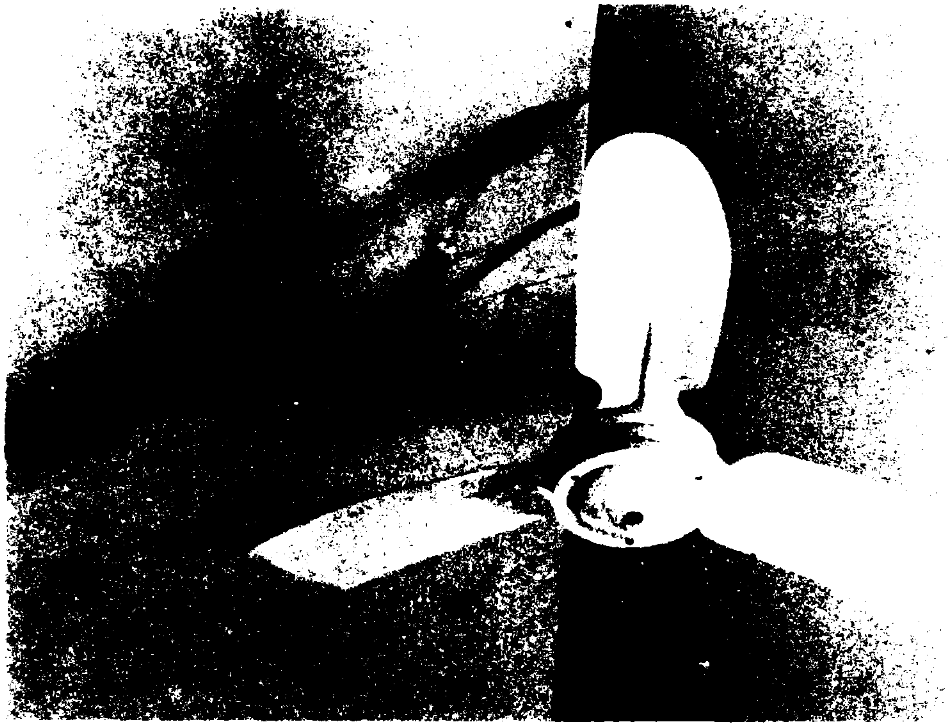


Figure 2. Ceiling fan.

- Cold air jet - NCEL (Figure 4): A blower sucks cool floor level air through a duct and injects this air as a high velocity air jet near the ceiling where it mixes with the hot ceiling level air. The design criteria for the NCEL cold air jet destratifier are presented in the Appendix.

- Heating system modification - LANTDIV (Figure 5): Hot ceiling level air is used as the intake air for the heating system's heating coils. The intake air can be routed to the heating system via a duct, or the heating coil's air intake can be located within the hot ceiling level air.

EVALUATION

Preliminary Evaluation of Commercial Destratifiers

The three commercial destratification units were evaluated at NCEL to determine their adaptability for use in hangars. All three were installed in a shop building at the laboratory and their effectiveness measured. The results of the evaluation are provided in Tables 1, 2, and 3 for the destratification tube, ceiling fan, and cold air blower, respectively. Figure 6 shows where the data were taken and the location of the destratifier within the building. As can be readily noted from the tables, while neither the ceiling fan nor the destratification tube produced any significant changes in the building's stratification characteristics, the cold air blower rapidly destratified the building.

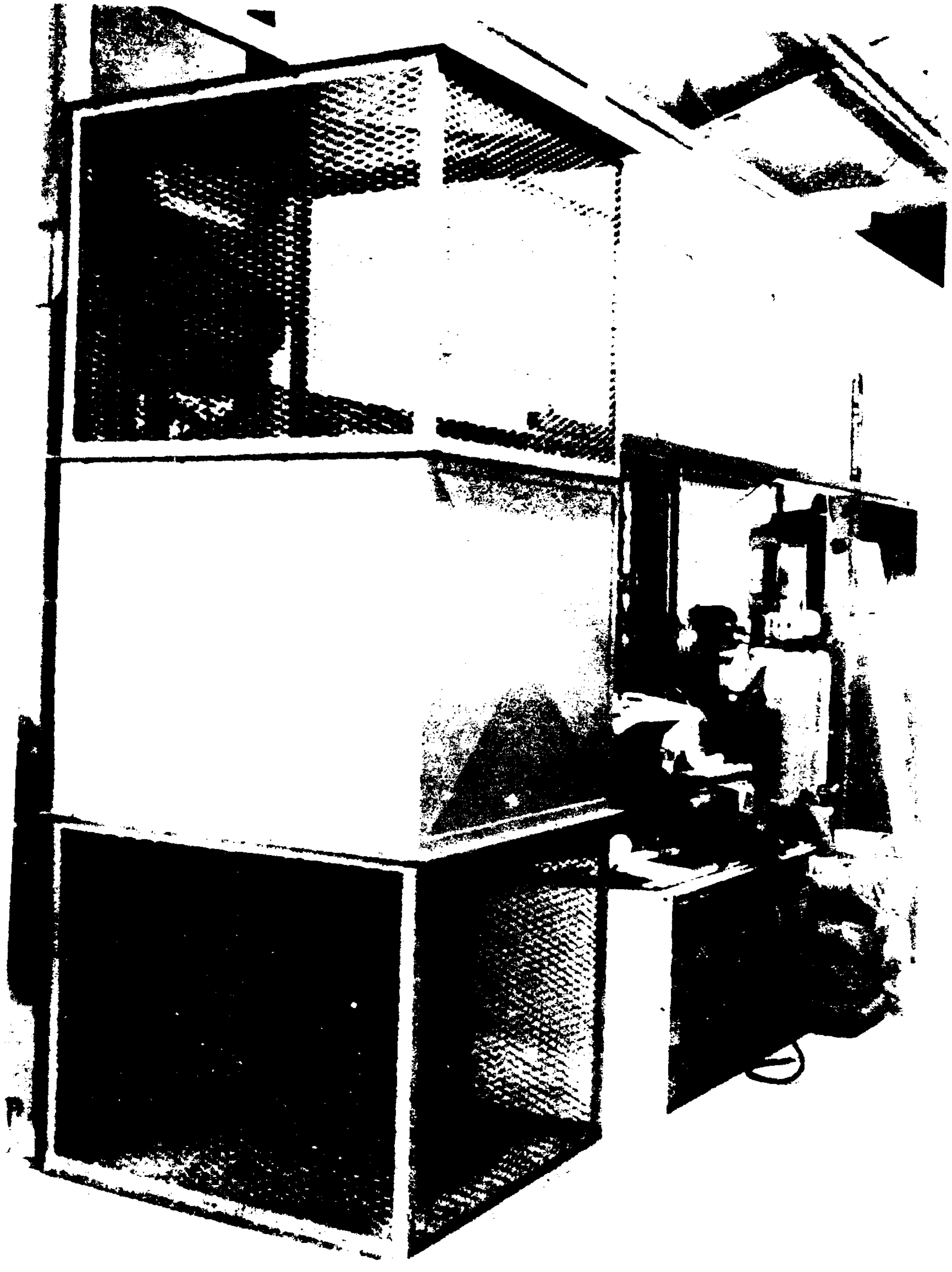
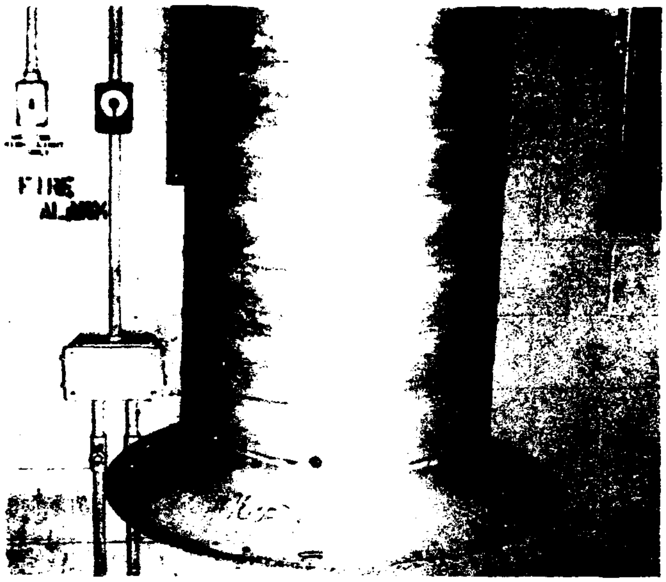


Figure 3. Floor blower.



(a) Duct near floor level.

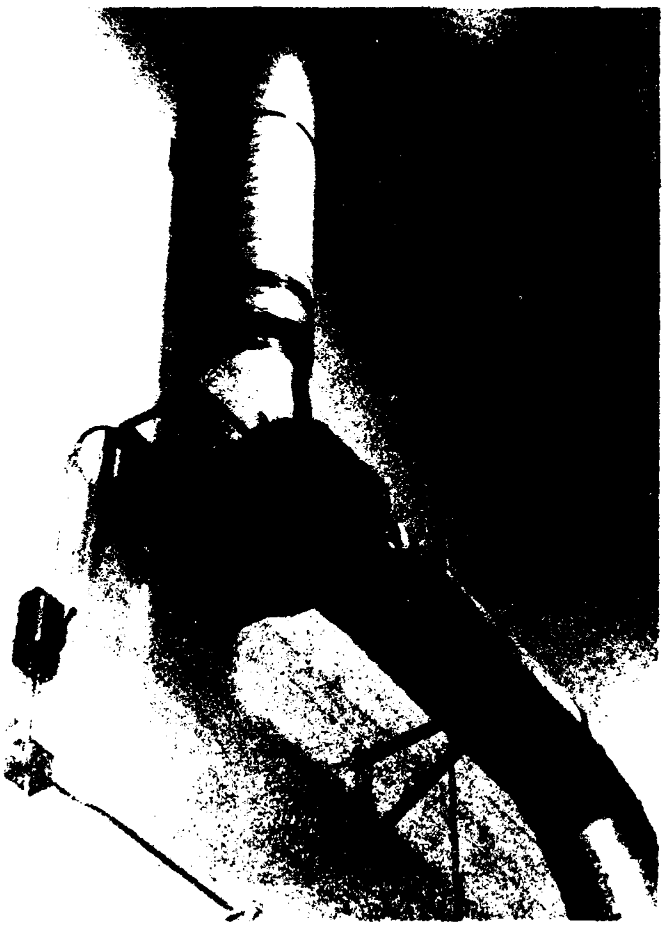
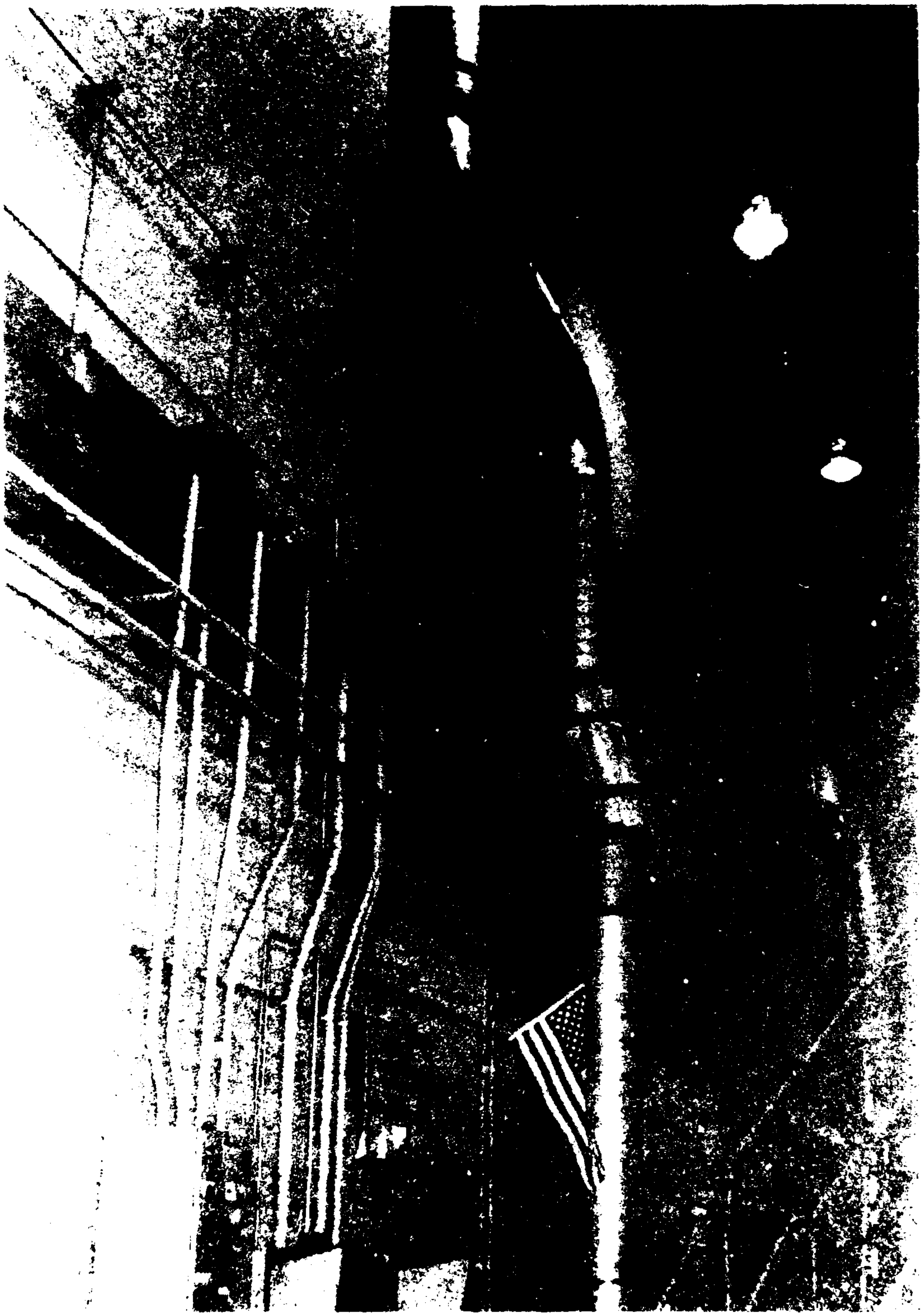
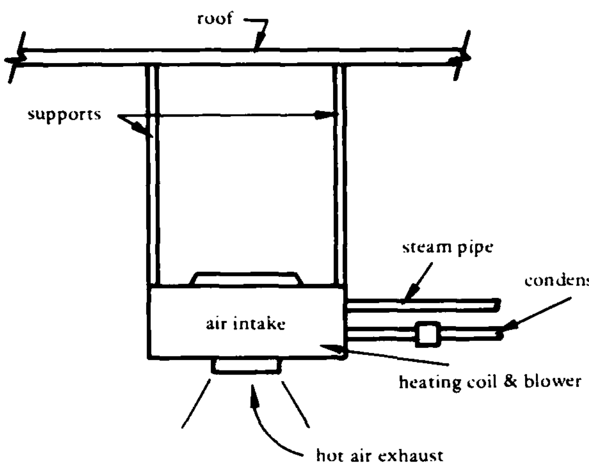

(b) Duct joint and blower.

Figure 4. Cold air jet.

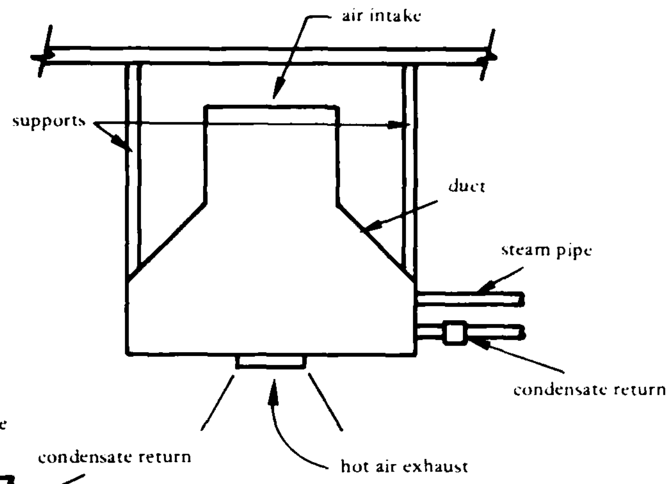


(c) Overall configuration.

Figure [illegible]. Continued.



(a) Existing.



(b) Modification.

Figure 5. LANTDIV heating system modification.

Table 1. Destratification Tube Evaluation, Building 564

Time	Data Point	Temperature (°F) at following Test Numbers				Avg
		1	2	3	4	
Ambient temperature 60°F; weather, cloudy; destratification tube placed in operation at 0917; floor/ceiling temperature difference, 26°F.						
0830	Floor Loft Ceiling	68 73 95	69 74 94	68 72 89	68 74 92	68 73 93
Ambient temperature, 62°F; weather, cloudy; data not taken at 10-ft level; floor/ceiling temperature difference, 26°F.						
1240	Floor Loft Ceiling	67 -- 95	68 -- 94	69 -- 93	68 -- 94	68 -- 94

Table 2. Ceiling Fan Evaluation, Building 564

Time	Data Point	Temperature (°F) at following Test Numbers				Avg
		1	2	3	4	
Destratification tube secured; ceiling fan placed in operation; floor/ceiling temperature difference, 25°F.						
1240	Floor Loft Ceiling	67 -- 95	68 -- 94	69 -- 93	68 -- 94	68 -- 94
Ambient temperature, 63°F; weather cloudy; floor/ceiling temperature difference, 21°F.						
1330	Floor Loft Ceiling	73 77 97	72 77 95	74 76 93	73 76 89	73 77 94

Table 3. Floor Air Blower Test Results, Building 564

Time	Data Point	Temperatures (°F) at Following Test Numbers					Avg
		1	2	3	4	5	
Ambient temperature 53°F; weather, rain. Destratifier not in operation; floor/ceiling temperature difference, 12°F.							
1000	Floor 10-ft high Ceiling	76 77 88	76 81 94	76 78 94	75 77 84	74 74 74	75 77 87
Ambient temperature, 53°F; weather, rain. Destratifier in operation at 1015; electric power consumption, 850 watts; floor/ceiling temperature difference, 1°F.							
1025	Floor 10-ft high Ceiling	77 75 76	77 76 76	79 80 84	76 75 75	77 77 80	77 77 78

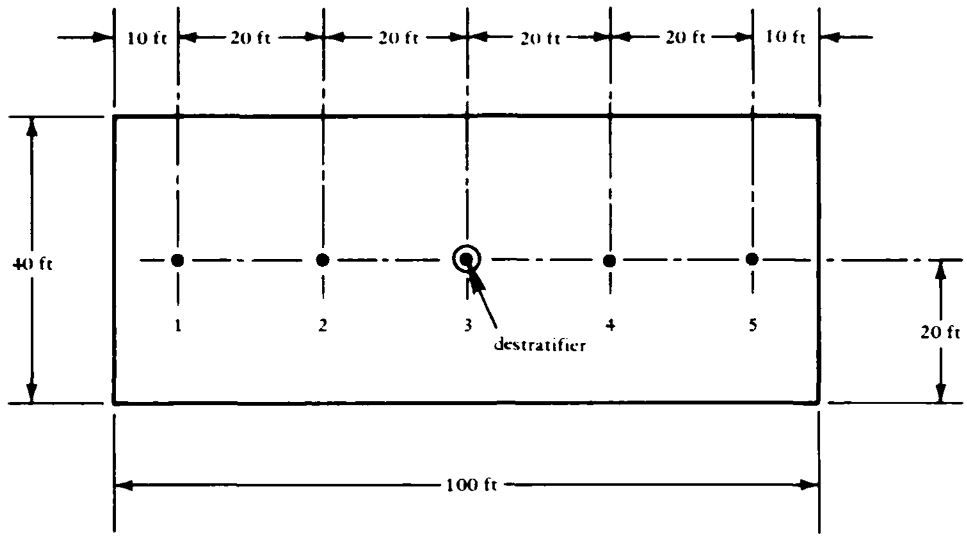


Figure 6. Location of data points and destratifier in test hangar.

The destratification tube and ceiling fan were then installed in a test chamber in order to determine if their effectiveness and installation criteria could be established. Tables 4 and 5 and Figures 7 and 8 provide the results of the chamber evaluation for the destratification tube and the ceiling fan, respectively. One installation parameter not measured at the evaluations conducted at NCEL was a maximum ceiling height. Although all three commercial concepts can destratify a structure, to varying degrees, and can save energy if properly installed, only the cold air blower indicated that it might be practically used to destratify a hangar. The number of units, height, and destratification effectiveness would have to be determined.

Installation and Evaluation for Chosen Systems

Destratifiers based upon the NCEL, LANTDIV, and cold air blower concepts were installed in Navy hangars and evaluated.

NCEL. The NCEL-designed destratifier, the cold air jet, was installed at the Navy Air Rework Facility, Norfolk, Va., in one of two bays in hangar V-147. Steam consumption was measured for both bays. Thermostat settings for both bays were kept at 55°F. Table 6 presents the reduction in steam consumption for the destratified bay versus the stratified bay. Based upon measurements made during parts of two heating seasons, the destratified bay consumed 29% less heating-related energy.

Table 4. NCEL Test Chamber Results, Destratification Tube

Item	Measurement
ΔT_s (floor/ceiling temperature difference, stratified)	38°F
ΔT_d (floor/ceiling temperature difference, destratified)	31°F
Destratification efficiency, $\frac{(\Delta T_s - \Delta T_d) \times 100}{\Delta T_s}$	18.5%
Test chamber volume, V	2,500 ft^3
Destratifier fan air movement, Q	6,300 ft^3/hr
Destratifier flow to volume ratio, Q/V	2.5
Destratifier electric power consumption, p	100 watts
Number of destratifier units required for installation in a building	$\frac{\text{Volume of building (room)}}{2.5 \times Q}$

Table 5. NCEL Test Results, Ceiling Fan

Characteristic	Test Number				
	1	2	3	4	5
Fan speed, rpm	240	160	120	90	60
Fan flow, ft^3/min, q	1,990	1,328	996	747	498
Fan flow, ft^3/hr, Q	119,000	79,680	59,760	44,820	29,880
ΔT_s, °F	32	29	29	29	32
ΔT_d, °F	6	10	17	27	32
Destratification efficiency, %	81	66	41	1	0
Test chamber volume, V	2,500	2,500	2,500	2,500	2,500
Q/V	47.5	32	24	18	12
Power, watts	173	150	138	127	115

Table 6. Comparison of Destratified (NCEL Concept) and Stratified Hangar, Building V147 at NARF Norfolk, Va.

[Electric power consumption: 240 VAC @ 3.2 amps/unit (7 units x 240 x 3 x 2 x 24 hr/day x 35 day/1,000 = 4,516 kWh); central steam plant efficiency = 68%; electric generation heat rate = 11,600 Btu/kWh; steam savings = 30%; net energy savings = 29%]

Date	Temperature, °F					Steam Consumption, MBtu		Steam Savings (MBtu)
	Outside	Destratified Bay		Stratified Bay		Destratified Bay	Stratified Bay	
		Floor	Ceiling	Floor[a]	Ceiling			
2/18/82	54	66	74	65	80	--[b]	--	--
2/19/82	54	66	80	65	83	213	292	79
2/25/82	47	65	74	65	86	889	792	<97>
2/26/82	35	69	74	65	86	280	430	150
3/3/82	42	69	74	65	82	999	1,259	260
3/5/82	44	68	74	65	82	298	229	<69>
3/8/82	32	67	76	65	88	341	715	374
1/14/83	48	68	--	--	--	--	--	--
1/18/83	51	69	--	--	--	138	621	483
1/20/83	43	65	--	--	--	244	606	362
1/24/83	48	71	--	--	--	1,447	2,076	629
1/27/83	46	62	--	--	--	545	443	<102>
1/31/83	50	66	--	--	--	672	1,213	541
Total						6,066	8,676	2,610

[a]Stratified bay floor level temperature was not measured, assumed to equal thermostat setting.

[b]-- = data not available.

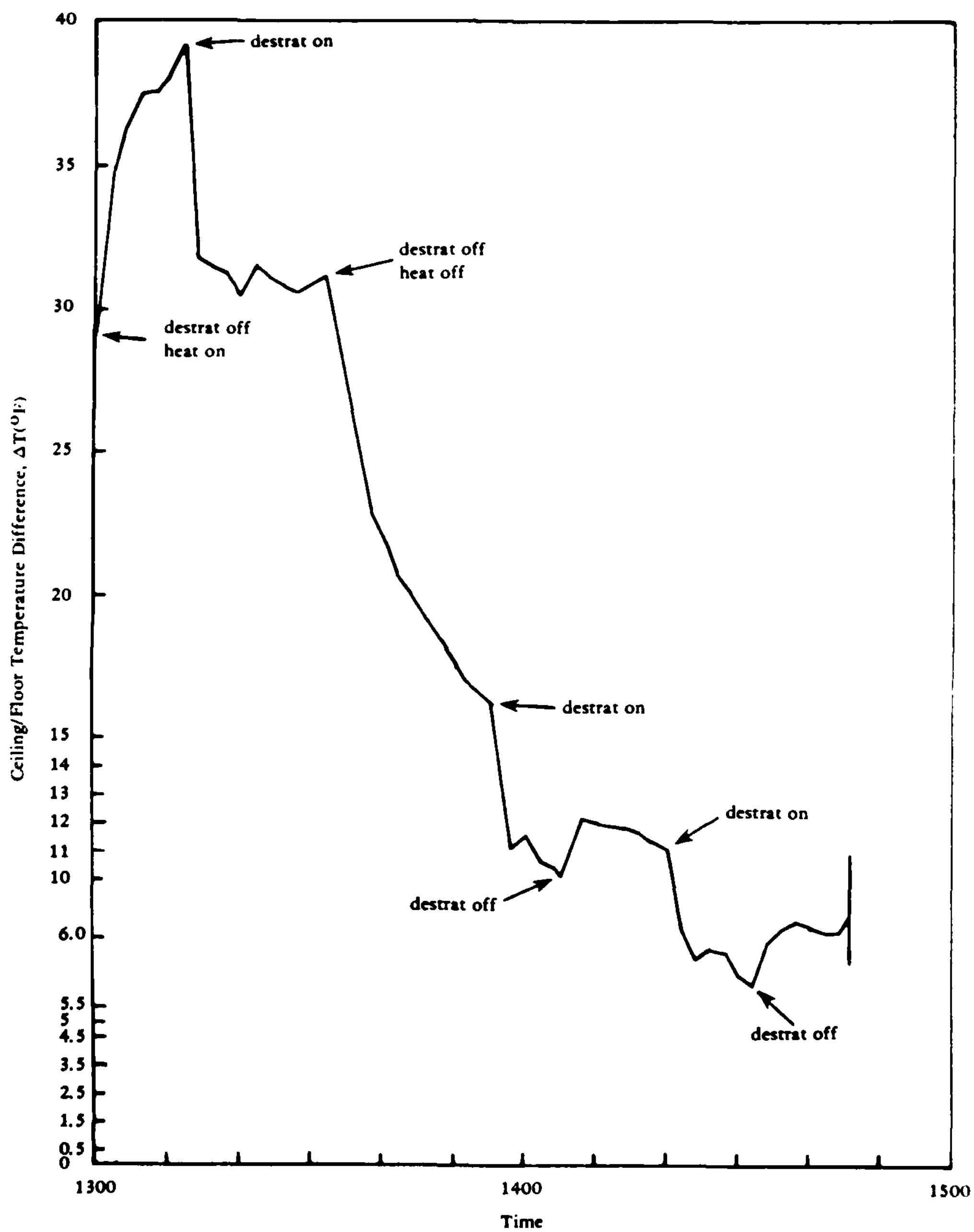


Figure 7. Destratification tube test chamber results.

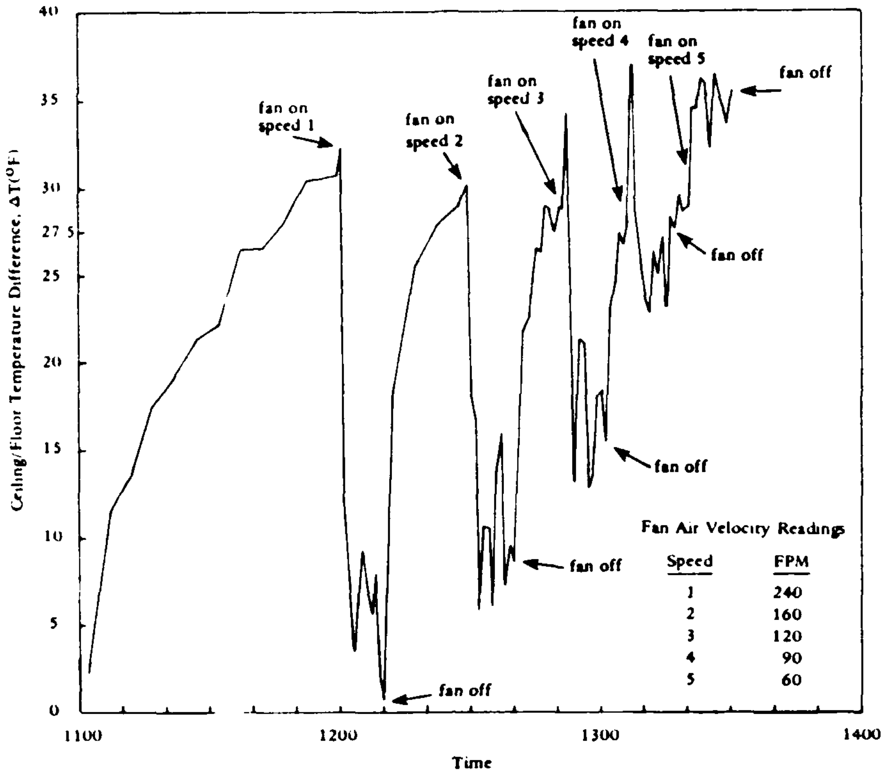


Figure 8. Ceiling fan test chamber results.

LANTDIV. The LANTDIV heating system modification was installed in the center section of a hangar located at the Naval Air Development Center (NADC), Warminster, Pa. (Figure 9, 10, and 11). Draft curtains across the hangar divided the overhead area into three sections of equal volumes. The draft curtains provided a solid barrier 15 feet deep from the roof down toward the floor. Thermocouple arrays were placed in two of the three sections (one with the LANTDIV destratifier modification and one without). Thermocouples for each section were placed at: (1) ceiling level directly above the hot air blower; (2) hangar centerline at ceiling level - 20 feet away from the hot air blower; (3) hangar centerline - 2, 4, 8, and 12 feet below the ceiling; and (4) center wall - 1 and 10 feet above the floor.

Hourly data were obtained for 3 months and recorded on a data logger. None of the thermocouples were calibrated to each other; thus only relative temperature differences were measured. Table 7 presents a synopsis of the data. The LANTDIV heating modification resulted in an average decrease of 2°F in the destratified section.

Cold-Air Blower. Three cold air blowers were installed, according to the manufacturer's recommendations in a hangar, also located at NADC Warminster (Figure 12). A thermocouple array was installed at the following locations: (1) on the hangar centerline - at the ceiling level and 2, 4, 8, and 12 feet below the ceiling; (2) 1 and 10 feet above the floor; and (3) outside.

Figure 9. Unit heater at NADC Warminster.

Figure 10. LANTDIV modification before installation at NADC Warminster.

Table 7. Temperatures Measured Before and After LANTDIV Modification Installation at NADC Warminster

Before Modification[a]				After Modification[b]			
Ceiling Bay No. 2	Ceiling Bay No. 3	Floor	Outside	Ceiling Bay No. 2[c]	Ceiling Bay No. 3	Floor	Outside
61	65	51	34	68	70	55	43
61	65	53	33	69	70	56	30
73	69	58	34	72	72	58	30
78	72	58	33	72	72	58	30
78	75	60	33	73	73	57	29
79	74	59	34	75	75	58	29
77	75	59	33	75	75	58	29
78	75	59	33	77	75	58	30
79	76	60	34	75	75	58	30
79	76	60	34	76	75	59	34
76	75	58	33	78	77	60	36
74	73	58	34	79	78	63	38
70	70	55	29	80	79	63	40
72	71	56	30	81	79	64	43
75	72	57	29	81	80	65	46
74	72	58	30	74	75	61	46
76	73	60	29	61	64	53	36
81	77	64	30	64	66	55	36
Average:							
74.5	72.5	57.6	32.7	73.9	73.9	58.8	33.7

[a]Ceiling (2)/Floor ΔT = 16.9°F
Ceiling (3)/Floor ΔT = 14.9°F
Average ceiling ΔT Bays 2/3 = 2°F

[b]Ceiling (2)/Floor ΔT = 15.1°F
Ceiling (3)/Floor ΔT = 15.1°F
Average ceiling ΔT Bays 2/3 = 0°F

[c]Modification installed in Bay No. 2.

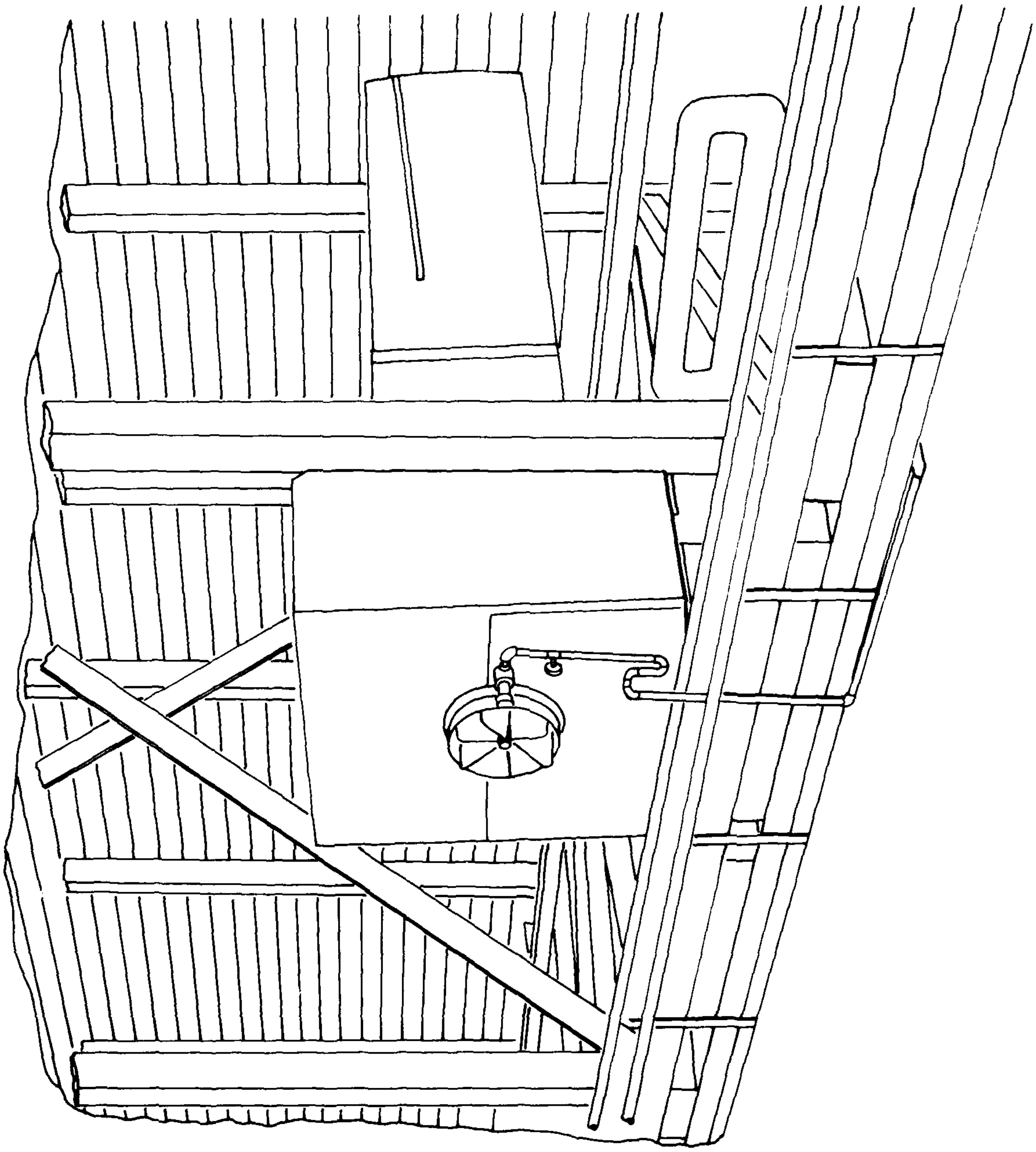


Figure 11. LANTDIV modification installed at NADC Warminster.

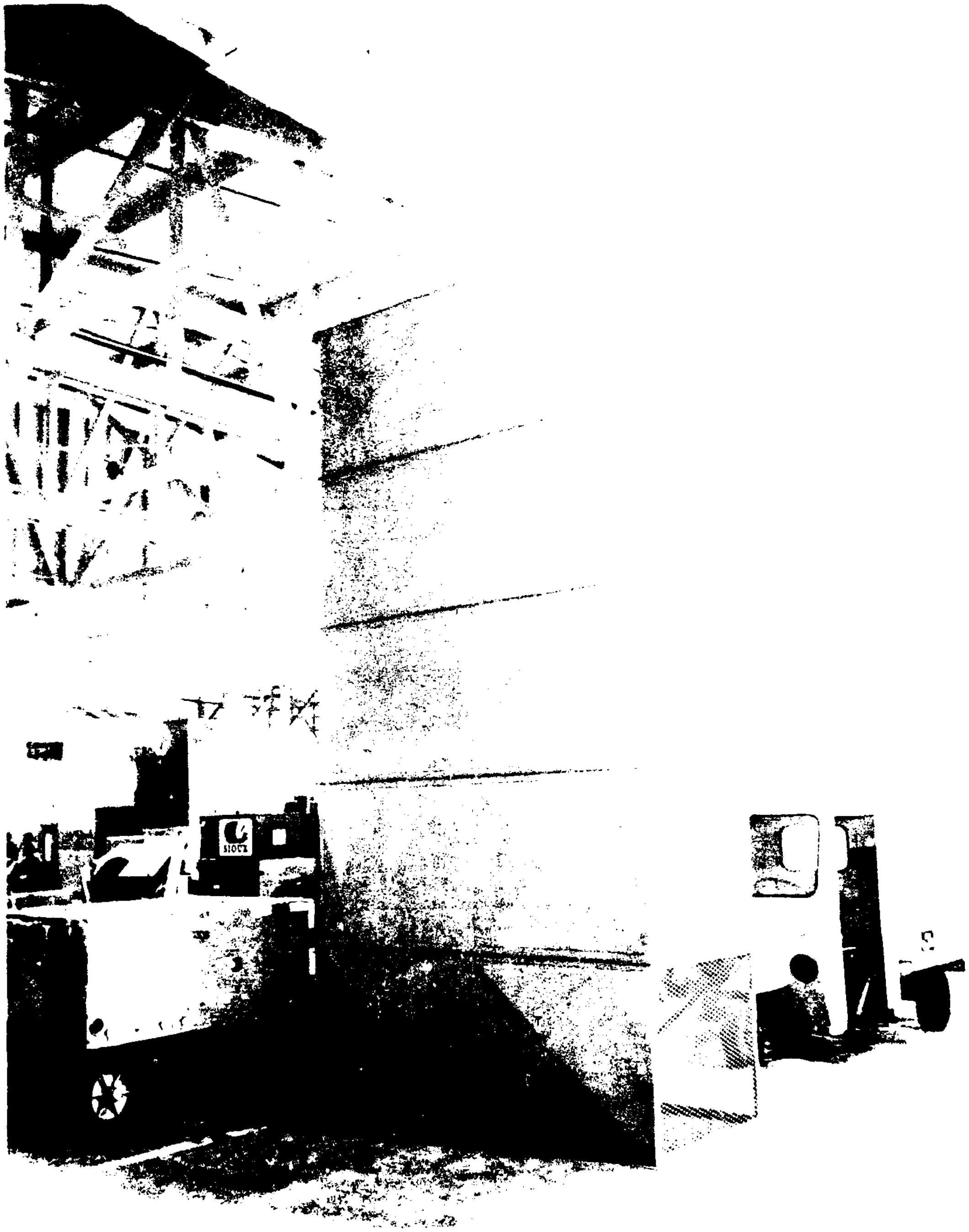


Figure 12. Cold air blower.

Hourly temperature measurements were made and recorded on a data logger during the 1982/83 winter. Data were obtained with and without the cold air blower in operation. A synopsis of the data is presented in Table 8 and Figure 13. As can be readily observed, the data are inconclusive with no definite indication of destratifier effectiveness.

CONCLUSIONS AND RECOMMENDATIONS

Of the five destratification concepts evaluated, only the NCEL cold jet destratifier and the LANTDIV modification produced meaningful results and are recommended for new and existing hangars. The cold air blower, the only commercial concept actually evaluated in a hangar, performed very well in a 25-foot-high building with the unit placed in the building's center. The hangar installation required that the units be placed along the structure's wall. Because of hangar width, height, and volume characteristics, either the cold air blower is not adaptable to hangar applications or additional units are required. Further tests are recommended to determine adaptability.

The LANTDIV heating system modification had a destratification efficiency of 11% and did save energy. Its cost ($3,500/heater) is not much less than the more efficient NCEL unit ($8,000/unit), therefore it is not recommended for retrofit. However, if the heating unit were located within 1 foot of the ceiling during installation of an original heating system, the additional cost required for the LANTDIV destratification would be negligible and the concept would prove most valuable during the life of the hangar. The LANTDIV concept is recommended for new hangars and for heating system replacements.

DESIGN CRITERIA FOR NCEL COLD AIR JET DESTRATIFIER

NCEL designed a cold air jet destratifier whose basis is the ability of an air jet to entrain surrounding air and to throw it across large distances. These principles are well-known and are documented in References 2 and 3. Figure 14 is a drawing of the destratifier. Design parameters are presented in Table 9 and can be used to design a destratifier for any hangar. The equations used for the destratifier system design are based upon principles stated in References 2 and 3 and are as follows:

$$Q = 0.00278\ V/N \tag{1}$$

where: Q = destratifier flow, ft^3/min

V = hangar volume, ft^3

N = number of destratifiers to be installed

Table 8. Temperatures Taken With Cold Air Blower, NADC Warminster

Temperature (°F)				Floor/Ceiling Temperature Difference (°F)
Ceiling	Floor	Outside	Floor/Outside	
Destratifier Off				
76	61	34	27	15
76	61	34	27	15
76	61	34	27	15
76	61	34	27	15
76	61	33	28	15
78	68	35	33	10
79	66	27	39	13
82	75	29	46	7
84	73	33	40	11
81	71	29	42	10
81	73	27	46	8
76	67	20	47	9
73	62	18	44	11
83	74	26	48	9
89	79	33	46	10
83	75	33	42	8
83	72	44	28	11
82	72	41	31	10
77	69	45	24	8
71	62	48	14	9
73	64	44	20	9
74	68	43	25	6
75	68	43	25	7
74	67	50	17	7
73	66	57	9	7
71	63	46	17	8
Destratifier On				
75	69	52	17	6
76	64	44	20	12
79	66	38	28	13
72	68	51	17	4
74	66	43	23	8
73	62	44	18	9
75	64	44	20	11
76	64	44	20	12
77	65	43	22	12
77	65	34	31	12
78	65	36	29	13
79	65	36	29	13
80	68	43	25	12
81	69	43	26	12
76	64	43	24	12
71	67	48	19	4
74	69	50	19	5

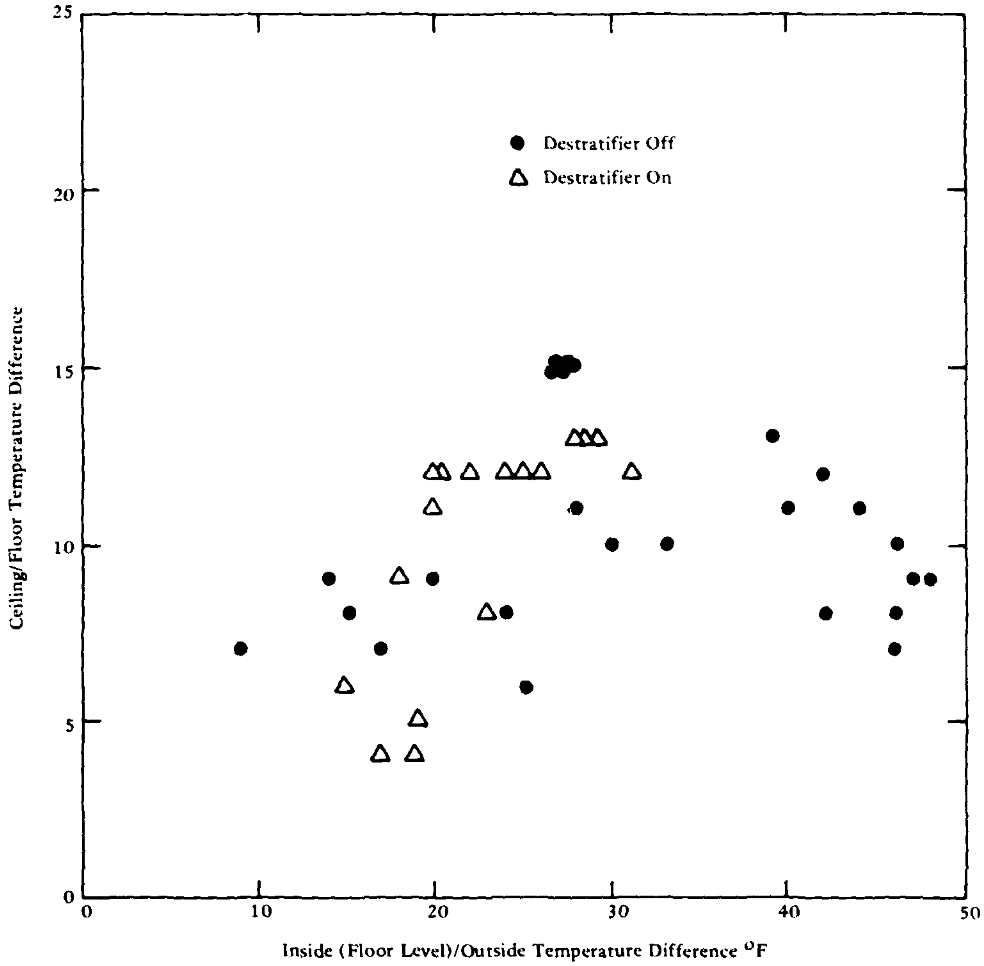


Figure 13. Cold air blower performance at NADC Warminster.

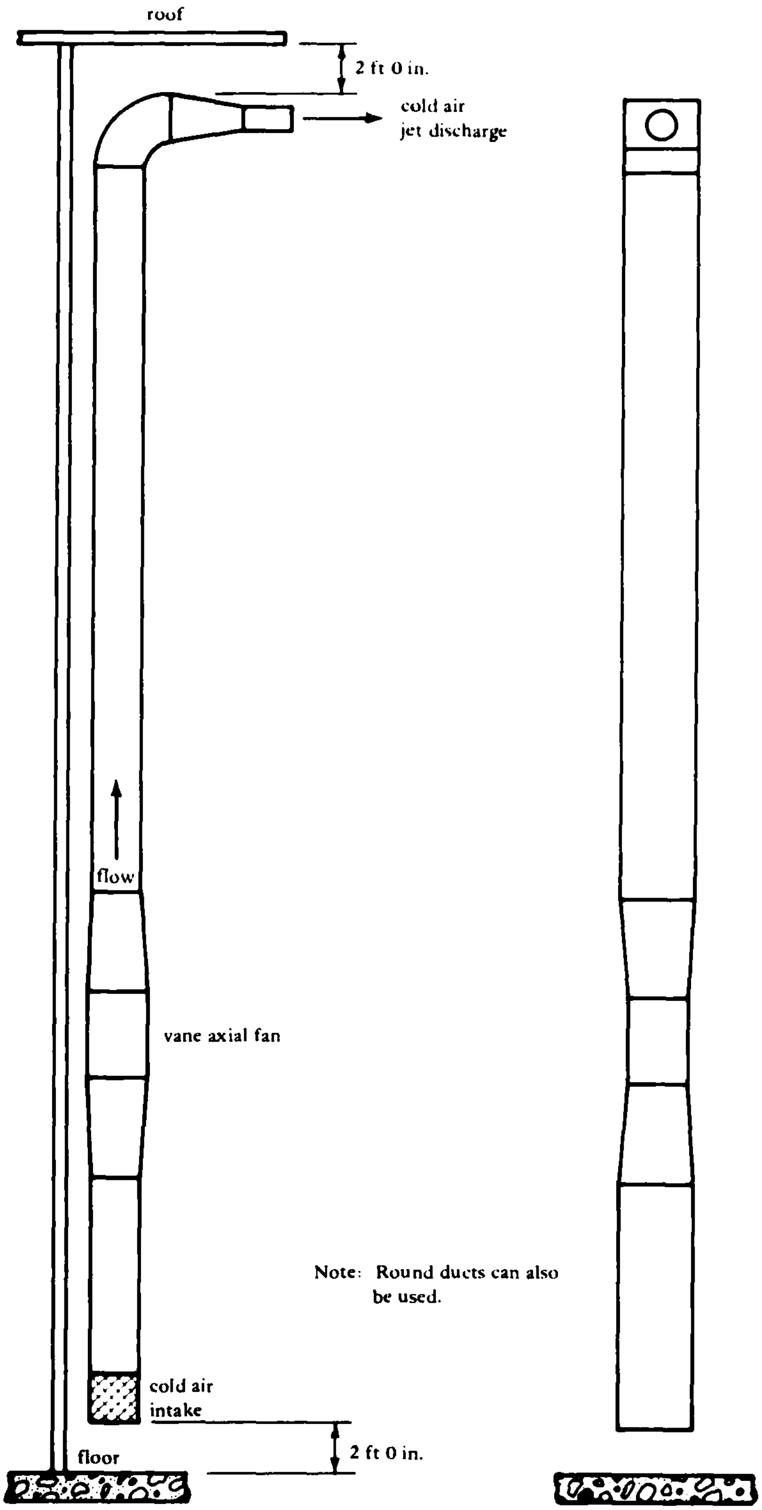


Figure 14. Cold floor air jet injection destratifier.

Table 9. Cold Air Jet Design Parameters

HANGAR VOLUME: 500000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
70	4	2000	1570	15.28
80	4	2000	2050	13.38
90	4	2000	2590	11.90
100	4	2000	3200	10.71
110	4	2000	3870	9.74

HANGAR VOLUME: 750000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
80	6	2000	2050	13.38
90	6	2000	2590	11.90
100	6	2000	3200	10.71
110	6	2000	3870	9.74
120	6	2000	4610	8.92
130	6	2000	5410	8.23
140	6	2000	6280	7.64

HANGAR VOLUME: 1000000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
90	6	3000	1730	17.83
100	6	3000	2130	16.07
110	6	3000	2580	14.60
120	6	3000	3070	13.39
130	6	3000	3610	12.34
140	6	3000	4180	11.47
150	6	3000	4800	10.71
160	6	3000	5460	10.04

HANGAR VOLUME: 1250000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
110	6	3500	2210	17.04
120	6	3500	2630	15.62
130	6	3500	3090	14.41
140	6	3500	3580	13.39
150	6	3500	4120	12.48
160	6	3500	4680	11.71
170	6	3500	5290	11.01
180	6	3500	5930	10.40

HANGAR VOLUME: 1500000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
120	6	4500	2050	20.06
130	6	4500	2400	18.54
140	6	4500	2790	17.20
150	6	4500	3200	16.06
160	6	4500	3640	15.06
170	6	4500	4110	14.17
180	6	4500	4610	13.38
190	6	4500	5140	12.67
200	6	4500	5690	12.04

HANGAR VOLUME: 1750000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
130	6	5000	2160	20.60
140	6	5000	2510	19.11
150	6	5000	2880	17.84
160	6	5000	3280	16.72
170	6	5000	3700	15.74
180	6	5000	4150	14.86
190	6	5000	4620	14.09
200	6	5000	5120	13.38
210	6	5000	5650	12.74
220	6	5000	6200	12.16

HANGAR VOLUME: 2000000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
140	6	5500	2280	21.03
150	6	5500	2620	19.62
160	6	5500	2980	18.40
170	6	5500	3360	17.33
180	6	5500	3770	16.36
190	6	5500	4200	15.50
200	6	5500	4660	14.71
210	6	5500	5130	14.02
220	6	5500	5640	13.37
230	6	5500	6160	12.80

HANGAR VOLUME: 2250000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
140	6	6500	1930	24.85
150	6	6500	2210	23.22
160	6	6500	2520	21.75
170	6	6500	2840	20.49
180	6	6500	3190	19.33
190	6	6500	3560	18.30
200	6	6500	3940	17.39
210	6	6500	4340	16.57
220	6	6500	4770	15.81
230	6	6500	5210	15.13
240	6	6500	5680	14.49
250	6	6500	6160	13.91

HANGAR VOLUME: 2500000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
150	6	7000	2060	24.96
160	6	7000	2340	23.42
170	6	7000	2640	22.05
180	6	7000	2960	20.82
190	6	7000	3300	19.72
200	6	7000	3660	18.73
210	6	7000	4030	17.85
220	6	7000	4430	17.02
230	6	7000	4840	16.29
240	6	7000	5270	15.61
250	6	7000	5720	14.98
260	6	7000	6190	14.40

HANGAR VOLUME: 2750000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
160	6	8000	2050	26.75
170	6	8000	2310	25.20
180	6	8000	2590	23.80
190	6	8000	2890	22.53
200	6	8000	3200	21.41
210	6	8000	3530	20.39
220	6	8000	3870	19.47
230	6	8000	4230	18.62
240	6	8000	4610	17.84
250	6	8000	5000	17.13
260	6	8000	5410	16.47
270	6	8000	5840	15.85
280	6	8000	6280	15.28

HANGAR VOLUME: 3000000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
170	6	9000	2050	28.37
180	6	9000	2300	26.79
190	6	9000	2570	25.34
200	6	9000	2840	24.11
210	6	9000	3140	22.93
220	6	9000	3440	21.90
230	6	9000	3760	20.95
240	6	9000	4100	20.06
250	6	9000	4450	19.26
260	6	9000	4810	18.52
270	6	9000	5190	17.83
280	6	9000	5580	17.20
290	6	9000	5980	16.61

HANGAR VOLUME: 3250000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
170	6	9000	2050	28.37
180	6	9000	2300	26.79
190	6	9000	2570	25.34
200	6	9000	2840	24.11
210	6	9000	3140	22.93
220	6	9000	3440	21.90
230	6	9000	3760	20.95
240	6	9000	4100	20.06
250	6	9000	4450	19.26
260	6	9000	4810	18.52
270	6	9000	5190	17.83
280	6	9000	5580	17.20
290	6	9000	5980	16.61
300	6	9000	6410	16.05

HANGAR VOLUME: 3500000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
180	6	10000	2070	29.76
190	6	10000	2310	28.18
200	6	10000	2560	26.76
210	6	10000	2820	25.50
220	6	10000	3100	24.32
230	6	10000	3390	23.26
240	6	10000	3690	22.29
250	6	10000	4000	21.41
260	6	10000	4330	20.58
270	6	10000	4670	19.82
280	6	10000	5020	19.11
290	6	10000	5390	18.45
300	6	10000	5760	17.84
310	6	10000	6160	17.25

HANGAR VOLUME: 3750000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
190	6	10500	2200	29.58
200	6	10500	2440	28.09
210	6	10500	2690	26.75
220	6	10500	2950	25.55
230	6	10500	3220	24.45
240	6	10500	3510	23.42
250	6	10500	3810	22.48
260	6	10500	4120	21.62
270	6	10500	4450	20.80
280	6	10500	4780	20.07
290	6	10500	5130	19.37
300	6	10500	5490	18.73
310	6	10500	5860	18.13
320	6	10500	6250	17.55

HANGAR VOLUME: 4000000 CUBIC FEET

DESTRATIFIER PARAMETERS

HANGAR WIDTH FEET	NUMBER UNITS	FLOW CFM	DISCHARGE VELOCITY FPM	NOZZLE DIAMETER INCHES
190	6	11000	2100	30.99
200	6	11000	2330	29.42
210	6	11000	2560	28.07
220	6	11000	2820	26.75
230	6	11000	3080	25.59
240	6	11000	3350	24.54
250	6	11000	3640	23.54
260	6	11000	3930	22.66
270	6	11000	4240	21.81
280	6	11000	4560	21.03
290	6	11000	4900	20.29
300	6	11000	5240	19.62
310	6	11000	5600	18.98
320	6	11000	5960	18.40
330	6	11000	6340	17.84

$$U = 0.022 U_T^2 W^2 / Q \qquad (2)$$

where: U = air exit velocity at destratifier nozzle, ft/min

U_T = residual air velocity at distance W, ft/min

W = throw distance, ft

$$D = 24\ (Q/\pi U)^{1/2} \qquad (3)$$

where D is the nozzle diameter, in.

For the design parameters presented in Table 9, a residual air velocity of 170 ft/min was assumed, and the hangar's width was used as the throw distance. The design data for nozzle diameter (Table 9), should be rounded to the nearest 1/4 inch. The recommended number of units is based upon moving a volume of air each hour equal to the interior volume of a hangar. Hangars, however, have their overhead areas sectionalized by draft curtains to curtail the spread of smoke and flame in case of fire. In some instances, the number of overhead sections will exceed the number of destratifier units recommended. In such circumstances, additional destratifiers are required so that at least one destratifier will be located within each section. Some older hangars have draft curtain designs which sectionalize the overhead in a shape similar to that of an egg crate. This will prevent the cold air jet destratifier from being effective. The LANTDIV heating system modification is the only concept evaluated which may be effective for an egg crate-sectionalized overhead.

REFERENCES

1. J.L. Ashley. Air infiltration and stratification investigation of Air Force and Navy aircraft hangars, Naval Civil Engineering Laboratory, Technical Report R-894. Port Hueneme, Calif., Jun 1982.

2. American Society of Heating, Refrigeration, Ventilation and Air Conditioning Engineers. ASHRAE guide and data book, fundamentals and equipment. New York, N.Y., ASHRAE 1963.

3. G.E. Wallin. "Reduce energy cost by utilizing ceiling heat," Plant Engineering, 20 Mar 1982, pp 86-87.

DISTRIBUTION LIST

ARMY Fal Engr. Letterkenny Army Depot. Chambersburg. PA
AFB (AFIT LDE). Wright Patterson OH; 82ABG DEMC. Williams AZ; ABG DEE (F. Nethers). Goodfellow AFB TX; AF Tech Office (Mgt & Ops). Tyndall. FL; CESCH. Wright-Patterson; HQ MAC DEEE. Scott. IL; SAMSO MNND. Norton AFB CA; Samso Dec (Sauer) Vandenburg. CA; Stinto Library. Offutt NE
AFESC DEB. Tyndall. FL
ARMY ARRADCOM. Dover. NJ; BMDSC-RE (H. McClellan) Huntsville AL; Contracts - Facs Engr Directorate. Fort Ord. CA; DAEN-CWE-M. Washington DC; DAEN-MPE-D Washington DC; DAEN-MPU. Washington DC; ERADCOM Tech Supp Dir. (DELSD-L) Ft. Monmouth. NJ; Natick R&D Command (Kwoh Hu) Natick MA. Tech. Ref. Div.. Fort Huachuca. AZ
ARMY - CERL Library. Champaign IL
ARMY CORPS OF ENGINEERS MRD-Eng. Div.. Omaha NE; Seattle Dist. Library. Seattle WA
ARMY CRREL G. Phetteplace Hanover. NH
ARMY ENGR DIST. Library. Portland OR
ARMY ENVIRON. HYGIENE AGCY HSE-LW Water Qual Eng Div Aberdeen Prov Grnd MD
ARMY MATERIALS & MECHANICS RESEARCH CENTER Dr. Lenoe. Watertown MA
ARMY MISSILE R&D CMD SCI Info Cen (DOC) Redstone Arsenal. AL
ARMY MTMC Trans Engr Agency MTT-CE. Newport News. VA
ADMINSUPU PWO. BAHRIAN
ASO PWD (ENS M W Davis). Phildadelphia. PA
BUREAU OF RECLAMATION Code 1512 (C. Selander) Denver CO
CINCLANT CIV ENGR SUPP PLANS OFFR NORFOLK. VA
CNAVRES Code 13 (Dir. Facilities) New Orleans. LA
CNM Code MAT-04. Washington. DC; Code MAT-08E. Washington. DC; NMAT - 044. Washington DC
CNO Code NOP-964. Washington DC; Code OP 987 Washington DC; Code OP-413 Wash. DC; Code OPNAV 09B24 (H); OP987J. Washington. DC
COMFLEACT. OKINAWA PWD - Engr Div. Sasebo. Japan; PWO. Kadena. Okinawa; PWO. Sasebo. Japan
COMNAVMARIANAS Code N4. Guam
COMOCEANSYSLANT PW-FAC MGMNT Off Norfolk. VA
COMOCEANSYSPAC SCE. Pearl Harbor HI
COMSUBDEVGRUONE Operations Offr. San Diego. CA
DEFFUELSUPPCEN DFSC-OWE (Term Engrng) Alexandria. VA; DFSC-OWE. Alexandria VA
DOE Div Ocean Energy Sys Cons/Solar Energy Wash DC; INEL Tech. Lib. (Reports Section). Idaho Falls. ID
DTIC Defense Technical Info Ctr/Alexandria. VA
DTNSRDC Code 4111 (R. Gierich). Bethesda MD
DTNSRDC Code 522 (Library). Annapolis MD
ENVIRONMENTAL PROTECTION AGENCY Reg. III Library. Philadelphia PA; Reg. VIII. 8M-ASL. Denver CO
FLTCOMBATTRACENLANT PWO. Virginia Bch VA
GIDEP OIC. Corona. CA
GSA Assist Comm Des & Cnst (FAIA) D R Dibner Washington. DC ; Off of Des & Const-PCDP (D Eakin) Washington. DC
HC & RS Tech Pres. Service. Meden. Washington. DC
LIBRARY OF CONGRESS Washington. DC (Sciences & Tech Div)
MARINE CORPS BASE Code 406. Camp Lejeune. NC; Maint Off Camp Pendleton. CA; PWD - Maint. Control Div. Camp Butler. Kawasaki. Japan; PWO Camp Lejeune NC; PWO. Camp Pendleton CA; PWO. Camp S. D. Butler. Kawasaki Japan
MARINE CORPS HQS Code LFF-2. Washington DC
MCAS Facil. Engr. Div. Cherry Point NC; CO. Kaneohe Bay HI; Code S4. Quantico VA; Facs Maint Dept - Operations Div. Cherry Point; PWD - Utilities Div. Iwakuni. Japan; PWO. Iwakuni. Japan; PWO. Yuma AZ
MCDEC NSAP REP. Quantico VA
MCLB B520. Barstow CA; Maintenance Officer. Barstow. CA; PWO. Barstow CA
MCRD SCE. San Diego CA
NAF PWD - Engr Div. Atsugi. Japan; PWO. Atsugi Japan
NALF OINC. San Diego. CA
NARF Code 100. Cherry Point. NC; Code 612. Jax. FL; Code 640. Pensacola FL; SCE Norfolk. VA
NAS CO. Guantanamo Bay Cuba; Code 114. Alameda CA; Code 183 (Fac. Plan BR MGR); Code 18700. Brunswick ME; Code 18U (ENS P.J. Hickey). Corpus Christi TX; Code 8E. Patuxent Riv.. MD; Dir of Engrng. PWD. Corpus Christi. TX; Grover. PWD. Patuxent River. MD; Lakehurst. NJ; Lead. Chief. Petty Offr. PW/Self Help Div. Beeville TX; PW (J. Maguire). Corpus Christi TX; PWD - Engr Div Dir. Millington. TN; PWD - Engr Div. Gtmo. Cuba; PWD - Engr Div. Oak Harbor. WA; PWD Maint. Cont. Dir.. Fallon NV; PWD Maint. Div.. New Orleans. Belle Chasse LA; PWD. Code 1821H (Pfankuch)

Miramar, SD CA; PWD, Maintenance Control Dir., Bermuda; PWO Belle Chasse, LA; PWO Chase Field Beeville, TX; PWO Key West FL; PWO Lakehurst, NJ; PWO Sigonella Sicily; PWO Whiting Fld, Milton FL; PWO, Dallas TX; PWO, Glenview IL; PWO, Millington TN; PWO, Miramar, San Diego CA; SCE Norfolk, VA; SCE, Barbers Point HI; SCE, Cubi Point, R.P

NATL RESEARCH COUNCIL Naval Studies Board, Washington DC

NAVACT PWO, London UK

NAVAEROSPREGMEDCEN SCE, Pensacola FL

NAVAIRDEVCEN Chmielewski, Warminster, PA; PWD, Engr Div Mgr, Warminster, PA

NAVAIRPROPTESTCEN CO, Trenton, NJ

NAVCOASTSYSCEN CO, Panama City FL; Code 715 (J Quirk) Panama City, FL; Library Panama City, FL; PWO Panama City, FL

NAVCOMMAREAMSTRSTA PWO, Norfolk VA; SCE Unit 1 Naples Italy; SCE, Wahiawa HI

NAVCOMMSTA Code 401 Nea Makri, Greece; PWD - Maint Control Div, Diego Garcia Is.; PWO, Exmouth, Australia; SCE, Balboa, CZ

NAVCONSTRACEN Curriculum Instr. Stds Offr, Gulfport MS

NAVEDTRAPRODEVCEN Technical Library, Pensacola, FL

NAVEDUTRACEN Engr Dept (Code 42) Newport, RI

NAVEODTECHCEN Code 605, Indian Head MD

NAVFAC PWO, Brawdy Wales UK; PWO, Centerville Bch, Ferndale CA; PWO, Point Sur, Big Sur CA

NAVFACENGCOM Alexandria, VA; Code 03 Alexandria, VA; Code 03T (Essoglou) Alexandria, VA; Code 04B3 Alexandria, VA; Code 051A Alexandria, VA; Code 09M54, Tech Lib, Alexandria, VA; Code 100 Alexandria, VA; Code 1113, Alexandria, VA; Code 111B Alexandria, VA; code 08T Alexandria, VA

NAVFACENGCOM - CHES DIV. Code 403 Washington DC; FPO-1 Washington, DC; Library, Washington, D.C.

NAVFACENGCOM - LANT DIV. Code 111, Norfolk, VA; Code 403, Norfolk, VA; Eur. BR Deputy Dir, Naples Italy; Library, Norfolk, VA; Code 1112, Norfolk, VA

NAVFACENGCOM - NORTH DIV. Code 04 Philadelphia, PA; Code 04AL, Philadelphia PA; Code 09P Philadelphia PA; Code 111 Philadelphia, PA; ROICC, Contracts, Crane IN

NAVFACENGCOM - PAC DIV. (Kyi) Code 101, Pearl Harbor, HI; CODE 09P PEARL HARBOR HI; Code 402, RDT&E, Pearl Harbor HI; Library, Pearl Harbor, HI

NAVFACENGCOM - SOUTH DIV. Code 403, Gaddy, Charleston, SC; Code 1112, Charleston, SC; Library, Charleston, SC

NAVFACENGCOM - WEST DIV. AROICC, Contracts, Twentynine Palms CA; Code 04B San Bruno, CA; Library, San Bruno, CA; O9P 20 San Bruno, CA; RDT&ELO San Bruno, CA

NAVFACENGCOM CONTRACTS AROICC, NAVSTA Brooklyn, NY; AROICC, Quantico, VA; Contracts, AROICC, Lemoore CA; Dir, Eng. Div., Exmouth, Australia; Eng Div dir, Southwest Pac, Manila, PI; OICC, Southwest Pac, Manila, PI; OICC-ROICC, NAS Oceana, Virginia Beach, VA; OICC ROICC, Balboa Panama Canal; ROICC AF Guam; ROICC Code 495 Portsmouth VA; ROICC Key West FL; ROICC MCAS El Toro; ROICC, Keflavik, Iceland; ROICC, NAS, Corpus Christi, TX; ROICC, Pacific, San Bruno CA; ROICC, Yap; ROICC-OICC-SPA, Norfolk, VA

NAVHOSP PWD - Engr Div, Beaufort, SC

NAVMAG PWD - Engr Div, Guam; SCE, Subic Bay, R.P.

NAVOCEANSYSCEN Code 4473B (Tech Lib) San Diego, CA; Code 523 (Hurley), San Diego, CA; Code 6700, San Diego, CA; Code 811 San Diego, CA

NAVORDMISTESTFAC PWD - Engr Dir, White Sands, NM

NAVORDSTA PWD - Dir, Engr Div, Indian Head, MD; PWO, Louisville KY

NAVPETOFF Code 30, Alexandria VA

NAVPETRES Director, Washington DC

NAVPHIBASE CO, ACB 2 Norfolk, VA; SCE Coronado, SD,CA

NAVREGMEDCEN PWD - Engr Div, Camp Lejeune, NC; PWO, Camp Lejeune, NC

NAVREGMEDCEN PWO, Okinawa, Japan

NAVREGMEDCEN SCE; SCE San Diego, CA; SCE, Camp Pendleton CA; SCE, Guam; SCE, Newport, RI; SCE, Oakland CA

NAVREGMEDCEN SCE, Yokosuka, Japan

NAVSCOLCECOFF C35 Port Hueneme, CA

NAVSCSOL PWO, Athens GA

NAVSEASYSCOM Code 0325, Program Mgr, Washington, DC; Code PMS 395 A 3, Washington, DC; SEA 04E (L Kess) Washington, DC

NAVSECGRUACT PWO, Adak AK; PWO, Edzell Scotland; PWO, Puerto Rico; PWO, Torri Sta, Okinawa

NAVSECSTA PWD - Engr Div, Wash., DC

NAVSHIPYD Code 202.4, Long Beach CA; Code 202.5 (Library) Puget Sound, Bremerton WA; Code 380, Portsmouth, VA; Code 382.3, Pearl Harbor, HI; Code 400, Puget Sound; Code 440 Portsmouth NH; Code 440, Norfolk; Code 440, Puget Sound, Bremerton WA; Code 453 (Util. Supr), Vallejo CA; Library, Portsmouth NH; PW Dept, Long Beach, CA; PWD (Code 420) Dir Portsmouth, VA; PWD (Code 450-HD) Portsmouth, VA; PWD (Code 453-HD) SHPO 03, Portsmouth, VA; PWO, Bremerton, WA; PWO, Mare Is.; PWO, Puget Sound; SCE, Pearl Harbor HI

NAVSTA Adak, AK; CO, Brooklyn NY; Code 4, 12 Marine Corps Dist, Treasure Is., San Francisco CA; Dir Engr Div, PWD, Mayport FL; Dir Mech Engr 37WC93 Norfolk, VA; Engr. Dir., Rota Spain; Long Beach, CA; Maint. Cont. Div., Guantanamo Bay Cuba; PWD - Engr Dept, Adak, AK; PWD - Engr Div, Midway Is., PWO, Keflavik Iceland; PWO, Mayport FL; SCE, Guam, Marianas; SCE, Pearl Harbor HI; SCE, San Diego CA; SCE, Subic Bay, R.P.; Utilities Engr Off. Rota Spain
NAVSUPPACT CO, Naples, Italy; PWO Naples Italy
NAVSUPPFAC PWD - Maint. Control Div, Thurmont, MD
NAVSURFWPNCEN PWO, White Oak, Silver Spring, MD
NAVTECHTRACEN SCE, Pensacola FL
NAVTELCOMMCOM Code 53, Washington, DC
NAVWPNCEN Code 2636 China Lake; PWO (Code 266) China Lake, CA; ROICC (Code 702), China Lake CA
NAVWPNSTA (Clebak) Colts Neck, NJ; Code 092, Concord CA; Code 092A, Seal Beach, CA
NAVWPNSTA PW Office Yorktown, VA
NAVWPNSTA PWD - Maint. Control Div., Concord, CA; PWD - Supr Gen Engr, Seal Beach, CA; PWO, Charleston, SC; PWO, Seal Beach CA
NAVWPNSUPPCEN Code 09 Crane IN
NCTC Const. Elec. School, Port Hueneme, CA
NCBC Code 10 Davisville, RI; Code 15, Port Hueneme CA; Code 155, Port Hueneme CA; Code 156, Port Hueneme, CA; Code 25111 Port Hueneme, CA; Code 430 (PW Engrng) Gulfport, MS; Code 470.2, Gulfport, MS; Library, Davisville, RI; NEESA Code 252 (P Winters) Port Hueneme, CA; PWO (Code 80) Port Hueneme, CA; PWO, Davisville RI; PWO, Gulfport, MS; Technical Library, Gulfport, MS
NMCB FIVE, Operations Dept; THREE, Operations Off.
NOAA (Mr. Joseph Vadus) Rockville, MD; Library Rockville, MD
NRL Code 5800 Washington, DC
NROTC J.W. Stephenson, UC, Berkeley, CA
NSC Code 54.1 Norfolk, VA
NSD SCE, Subic Bay, R.P.
NSWSES Code 0150 Port Hueneme, CA
NUSC DET Code 131 New London, CT; Code 5202 (S. Schady) New London, CT; Code EA123 (R.S. Munn), New London CT; Code SB 331 (Brown), Newport RI
OFFICE SECRETARY OF DEFENSE OASD (MRA&L) Dir. of Energy, Pentagon, Washington, DC
ONR Code 221, Arlington VA; Code 700F Arlington VA
PACMISRANFAC HI Area Bkg Sands, PWO Kekaha, Kauai, HI
PHIBCB 1 P&E, San Diego, CA
PWC ACE Office Norfolk, VA; CO, (Code 10), Oakland, CA; Code 10, Great Lakes, IL; Code 105 Oakland, CA; Code 110, Great Lakes, IL; Code 110, Oakland, CA; Code 120, Oakland CA; Code 154 (Library), Great Lakes, IL; Code 200, Great Lakes IL; Code 400, Great Lakes, IL; Code 400, Pearl Harbor, HI; Code 400, San Diego, CA; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Code 424, Norfolk, VA; Code 500 Norfolk, VA; Code 505A Oakland, CA; Code 600, Great Lakes, IL; Code 610, San Diego Ca; Code 700, Great Lakes, IL; Library, Code 120C, San Diego, CA; Library, Guam; Library, Norfolk, VA; Library, Pearl Harbor, HI; Library, Pensacola, FL; Library, Subic Bay, R.P.; Library, Yokosuka JA; Util Dept (R Pascua) Pearl Harbor, HI; Utilities Officer, Guam
SPCC PWO (Code 120) Mechanicsburg PA
TVA Smelser, Knoxville, Tenn.; Solar Group, Arnold, Knoxville, TN
U.S. MERCHANT MARINE ACADEMY Kings Point, NY (Reprint Custodian)
USAF REGIONAL HOSPITAL Fairchild AFB, WA
US GEOLOGICAL SURVEY (Chas E. Smith) Minerals Mgmt Serv, Reston, VA
USCG G-MMT-4/82 (J Spencer); Library Hqs Washington, DC
USCG R&D CENTER Library New London, CT
USDA Forest Service Reg 3 (R. Brown) Albuquerque, NM
USNA Ch. Mech. Engr. Dept Annapolis MD; ENGRNG Div, PWD, Annapolis MD; Energy-Environ Study Grp, Annapolis, MD; Environ. Prot. R&D Prog. (J. Williams), Annapolis MD; Mech. Engr. Dept. (C. Wu), Annapolis MD; USNA/SYS ENG DEPT ANNAPOLIS MD
USS FULTON WPNS Rep. Offr (W-3) New York, NY
ARIZONA Kroelinger Tempe, AZ; State Energy Programs Off., Phoenix AZ
AUBURN UNIV. Bldg Sci Dept, Lechner, Auburn, AL
BERKELEY PW Engr Div, Harrison, Berkeley, CA
BONNEVILLE POWER ADMIN Portland OR (Energy Consrv. Off., D. Davey)
BROOKHAVEN NATL LAB M. Steinberg, Upton NY
CALIFORNIA STATE UNIVERSITY LONG BEACH, CA (CHELAPATI)
CONNECTICUT Office of Policy & Mgt, Energy, Div, Hartford, CT
CORNELL UNIVERSITY Ithaca NY (Serials Dept, Engr Lib.)
DAMES & MOORE LIBRARY LOS ANGELES, CA
DRURY COLLEGE Physics Dept, Springfield, MO
FLORIDA ATLANTIC UNIVERSITY Boca Raton, FL (McAllister)
FOREST INST. FOR OCEAN & MOUNTAIN Carson City NV (Studies - Library)

GEORGIA INSTITUTE OF TECHNOLOGY (LT R. Johnson) Atlanta, GA; Col. Arch. Benton, Atlanta, GA
HARVARD UNIV. Dept. of Architecture, Dr. Kim, Cambridge, MA
HAWAII STATE DEPT OF PLAN. & ECON DEV. Honolulu HI (Tech Info Ctr)
IOWA STATE UNIVERSITY Dept. Arch. McKrown, Ames, IA
WOODS HOLE OCEANOGRAPHIC INST Woods Hole MA (Winget)
KEENE STATE COLLEGE Keene NH (Cunningham)
LEHIGH UNIVERSITY Bethlehem PA (Linderman Lib. No 30, Flecksteiner)
LOUISIANA DIV NATURAL RESOURCES & ENERGY Div Of R&D, Baton Rouge, LA
MAINE OFFICE OF ENERGY RESOURCES Augusta, ME
MISSOURI ENERGY AGENCY Jefferson City MO
MIT Cambridge MA (Rm 10-500, Tech. Reports, Engr. Lib.), Cambridge, MA (Harleman)
MONTANA ENERGY OFFICE Anderson, Helena, MT
NATURAL ENERGY LAB Library, Honolulu, HI
NEW HAMPSHIRE Concord NH (Governor's Council on Energy)
NEW MEXICO SOLAR ENERGY INST. Dr. Zwibel Las Cruces NM
NY CITY COMMUNITY COLLEGE BROOKLYN, NY (LIBRARY)
NYS ENERGY OFFICE Library, Albany NY
OAK RIDGE NATL LAB T. Lundy, Oak Ridge, TN
PURDUE UNIVERSITY Lafayette, IN (CE Engr. Lib)
SCRIPPS INSTITUTE OF OCEANOGRAPHY LA JOLLA, CA (ADAMS)
SEATTLE U Prof Schwaegler Seattle WA
SRI INTL Phillips, Chem Engr Lab, Menlo Park, CA
STATE UNIV. OF NEW YORK Fort Schuyler, NY (Longobardi)
STATE UNIV. OF NY AT BUFFALO School of Medicine, Buffalo, NY
TEXAS A&M UNIVERSITY W.B. Ledbetter College Station, TX
UNIVERSITY OF CALIFORNIA Energy Engineer, Davis CA; LIVERMORE, CA (LAWRENCE LIVERMORE LAB, TOKARZ); UCSF, Physical Plant, San Francisco, CA
UNIVERSITY OF DELAWARE Newark, DE (Dept of Civil Engineering, Chesson)
UNIVERSITY OF FLORIDA Dept Arch., Morgan, Gainesville, FL
UNIVERSITY OF HAWAII HONOLULU, HI (SCIENCE AND TECH. DIV.)
UNIVERSITY OF ILLINOIS (Hall) Urbana, IL; URBANA, IL (LIBRARY)
UNIVERSITY OF MASSACHUSETTS (Heronemus), ME Dept, Amherst, MA
UNIVERSITY OF NEBRASKA-LINCOLN Lincoln, NE (Ross Ice Shelf Proj.)
UNIVERSITY OF NEW HAMPSHIRE Elec. Engr. Depot, Dr. Murdoch, Durham, N.H
UNIVERSITY OF TEXAS Inst. Marine Sci (Library), Port Arkansas TX
UNIVERSITY OF TEXAS AT AUSTIN AUSTIN, TX (THOMPSON)
UNIVERSITY OF WASHINGTON Seattle WA (E. Linger)
UNIVERSITY OF WISCONSIN Milwaukee WI (Ctr of Great Lakes Studies)
ARVID GRANT OLYMPIA, WA
ATLANTIC RICHFIELD CO. DALLAS, TX (SMITH)
BECHTEL CORP. SAN FRANCISCO, CA (PHELPS)
BROWN & ROOT Houston TX (D. Ward)
CHEMED CORP Lake Zurich IL (Dearborn Chem. Div.Lib.)
COLUMBIA GULF TRANSMISSION CO. HOUSTON, TX (ENG. LIB.)
DESIGN SERVICES Beck, Ventura, CA
DIXIE DIVING CENTER Decatur, GA
DURLACH, O'NEAL, JENKINS & ASSOC. Columbia SC
GARD INC. Dr. L. Holmes, Niles, IL
LITHONIA LIGHTING Application eng. Dept. (B. Helton), Conyers, GA 30207
MCDONNEL AIRCRAFT CO. (Fayman) Engrng Dept., St. Louis, MO
MEDERMOTT & CO. Diving Division, Harvey, LA
NEWPORT NEWS SHIPBLDG & DRYDOCK CO. Newport News VA (Tech. Lib.)
PACIFIC MARINE TECHNOLOGY (M. Wagner) Duvall, WA
PG&E Library, San Francisco, CA
PORTLAND CEMENT ASSOC. Skokie IL (Rsch & Dev Lab, Lib.)
RAYMOND INTERNATIONAL INC. E Colle Soil Tech Dept, Pennsauken, NJ
SANDIA LABORATORIES Albuquerque, NM (Vortman); Library Div., Livermore CA
SCHUPACK ASSOC SO. NORWALK, CT (SCHUPACK)
SHELL DEVELOPMENT CO. Houston TX (C. Sellars Jr.)
TEXTRON INC BUFFALO, NY (RESEARCH CENTER LIB.)
TRW SYSTEMS REDONDO BEACH, CA (DAI)
UNITED TECHNOLOGIES Windsor Locks CT (Hamilton Std Div., Library)
WARD, WOLSTENHOLD ARCHITECTS Sacramento, CA
WESTINGHOUSE ELECTRIC CORP. Annapolis MD (Oceanic Div Lib, Bryan); Library, Pittsburgh PA
WM CLAPP LABS - BATTELLE DUXBURY, MA (LIBRARY)

BRAHTZ La Jolla, CA
FISHER San Diego, Ca
KETRON, BOB Ft Worth, TX
KRUZIC, T.P. Silver Spring, MD
T.W. MERMEL Washington DC
WALTZ Livermore, CA

INSTRUCTIONS

The Naval Civil Engineering Laboratory has revised its primary distribution lists. The bottom of the mailing label has several numbers listed. These numbers correspond to numbers assigned to the list of Subject Categories. Numbers on the label corresponding to those on the list indicate the subject category and type of documents you are presently receiving. If you are satisfied, throw this card away (or file it for later reference).

If you want to change what you are presently receiving:

- Delete – mark off number on bottom of label.
- Add – circle number on list.
- Remove my name from all your lists – check box on list.
- Change my address – line out incorrect line and write in correction (ATTACH MAILING LABEL).
- Number of copies should be entered after the title of the subject categories you select.

Fold on line below and drop in the mail.

Note: Numbers on label but not listed on questionnaire are for NCEL use only, please ignore them.

Fold on line and staple.

DEPARTMENT OF THE NAVY

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300
1 IND-NCEL-2700/4 (REV. 12-73)
0930-LL-L70-0044

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316

U.S.MAIL

Commanding Officer
Code L14
Naval Civil Engineering Laboratory
Port Hueneme, California 93043

DISTRIBUTION QUESTIONNAIRE

The Naval Civil Engineering Laboratory is revising its primary distribution lists.

SUBJECT CATEGORIES

1 **SHORE FACILITIES**
2 Construction methods and materials (including corrosion control, coatings)
3 Waterfront structures (maintenance/deterioration control)
4 Utilities (including power conditioning)
5 Explosives safety
6 Construction equipment and machinery
7 Fire prevention and control
8 Antenna technology
9 Structural analysis and design (including numerical and computer techniques)
10 Protective construction (including hardened shelters, shock and vibration studies)
11 Soil/rock mechanics
13 BEQ
14 Airfields and pavements
15 **ADVANCED BASE AND AMPHIBIOUS FACILITIES**
16 Base facilities (including shelters, power generation, water supplies)
17 Expedient roads/airfields/bridges
18 Amphibious operations (including breakwaters, wave forces)
19 Over-the-Beach operations (including containerization, materiel transfer, lighterage and cranes)
20 POL storage, transfer and distribution
24 **POLAR ENGINEERING**
24 Same as Advanced Base and Amphibious Facilities, except limited to cold-region environments
28 **ENERGY/POWER GENERATION**
29 Thermal conservation (thermal engineering of buildings, HVAC systems, energy loss measurement, power generation)
30 Controls and electrical conservation (electrical systems, energy monitoring and control systems)
31 Fuel flexibility (liquid fuels, coal utilization, energy from solid waste)
32 Alternate energy source (geothermal power, photovoltaic power systems, solar systems, wind systems, energy storage systems)
33 Site data and systems integration (energy resource data, energy consumption data, integrating energy systems)
34 **ENVIRONMENTAL PROTECTION**
35 Solid waste management
36 Hazardous/toxic materials management
37 Wastewater management and sanitary engineering
38 Oil pollution removal and recovery
39 Air pollution
40 Noise abatement
44 **OCEAN ENGINEERING**
45 Seafloor soils and foundations
46 Seafloor construction systems and operations (including diver and manipulator tools)
47 Undersea structures and materials
48 Anchors and moorings
49 Undersea power systems, electromechanical cables, and connectors
50 Pressure vessel facilities
51 Physical environment (including site surveying)
52 Ocean-based concrete structures
53 Hyperbaric chambers
54 Undersea cable dynamics

TYPES OF DOCUMENTS

85 *Techdata Sheets*
86 Technical Reports and Technical Notes
82 NCEL Guide & Updates
☐ None – remove my name
83 Table of Contents & Index to TDS
91 Physical Security